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AN OPTIMIZATION OF MECHANICAL PROPERTIES OF FRICTION STIR WELDED DISSIMILAR MATERIALS WITH DIFFERENT PREHEATING CONDITIONS

PRASHANT S. HUMNABAD[1] & M. S. GANESHA PRASAD[2]

[1]*Research Scholar, Faculty of Department of Mechanical Engineering, Sir M. Visvesvaraya Institute of Technology, Bengaluru, Karnataka, India*

[2]*Dean, Professor and Head, Department of Mechanical Engineering, New Horizon College of Engineering, Bengaluru, Karnataka, India*

ABSTRACT

The aim of this work is to optimization of the mechanical properties of friction stir welded dissimilar materials with different preheating temperature. A series of joints were made on 04 mm thick Aluminum7xxx and Mild-Steel plates. The temperature used to be 100ºC, 150 ºC and 200 ºC. The welding operation performed with different rotational speeds and traverse speed (1000, 1400 and 2000 ramp and 16, 20 and 25 mm/min) the mechanical properties were measured with respect to tensile strength, impact strength and hardness. The physical properties were examined based on the microstructure using optical microscope. The results show that weld with 150 ºC, 16 mm/min and 1400 rpm parameter exhibit the better joint strength of 130.36 MPa.

***KEYWORDS:** Preheating Temperature, Friciton Stir Welding, Mechanical Properites & Microstructure*

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Original Article

INTRODUCTION

Background Information

To produce components with dissimilar materials like ferrous and non-ferrous materials (such as - steel and aluminium) by fusion welding method is quite difficult, it's because formation of hard (or) brittle intermetallic compounds at weld interface. Hence, a new technology is highly desirable to join these materials requires

To produce a good quality weld of steel/aluminium joint, the Solid-State Welding method is more suitable than other welding processes, since it requires less diffusion bonding time compared to other welding methods. Also, lower welding temperature and almost no formation toxic gases. This technique can be used to weld dissimilar materials such as ferrous and non-ferrous materials, metal matrix composite materials and also variety of joint types can be produced (proper fixture should be designed and manufactured to hold the work pieces firmly during operation).

It is a process where, Ferrous to Non-Ferrous materials can be welded; the workpieces were joined under the pressure or a combination of both heat and pressure. The base metal remains in the solid state, because the temperature will not be more than the melting point of the base metal. If external heat is applied, it should be lower than base metal melting point temperature.

Figure 1 shows Friction Stir Welding (FSW) which is one of the kind of Deformation welding process.

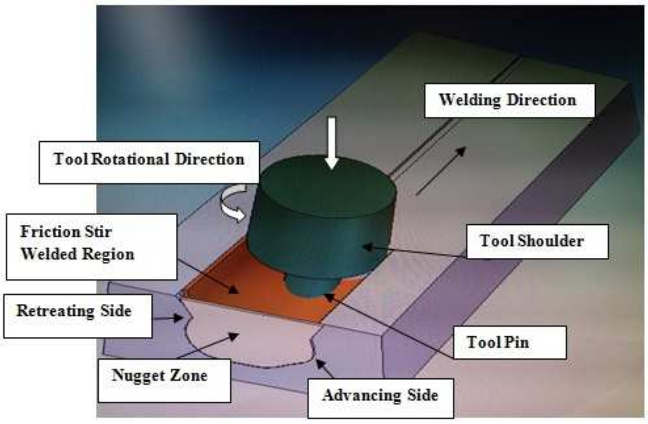

Figure 1: Schematic Representation of Friction Stir Welding

A newly developed technique Friction Stir Welding (FSW) is the new trend in solid state joining method and used for aluminium alloy, as well as for magnesium, copper, titanium and steel. It was first developed and experimented by W. Thomas at The Welding Institute (TWI), UK, in December 1991.

Friction-Stir Welding (FSW) is a solid-state joining process (the metal is not melted, the metal turns into paste form which is pressed in the gap between two plates by the moving tool shoulder. Hence this paste joins both the plates). It mechanically intermixes the two pieces of metal at the place of the join, then softens them so the metal can be fused using mechanical pressure.

Friction Stir Welding (FSW) is used for the applications where original metal characteristics must remain unchanged as far as possible. It is a continuous hot shear process involving a non-consumable, rotating probe of harder material than the base metals to be joined. The friction between the rotating tool and the work-piece heats and softens the metal adjacent to the tool so that it can readily flow around. Thus, the sources of heat in FSW are: The friction between the tool and work-piece and The severe plastic deformation occurring in the material.

Friction Stir Welding was used already in routine, as well as in critical applications for the joining of structural components mainly made of aluminium and its alloys. However, further studies are still being carried out in order to obtain a more robust "process window". The friction stir welding joints between steel and aluminium alloy have been reported earlier [1-4]. In fact, Kimapong and Watanabe have reported that a sound butt joint between AA5083 and steel was successfully formed by FSW [5].

MATERIAL AND EXPERIMENTATION

The materials selected for the present research work are commercially available Mild-Steel and Aluminium-7xxx in the form of plates of size (lbh) 100 x 50 x 4 mm respectively.

Mild-Steel Properties: Table 1 illustrates the Mechanical Properties of Mild-Steel.

Table 1: Mechanical Properties of Mild Steel

Mechanical Properties	Metric
Impact strength	64 (J)
Hardness, Vickers	140.6
Tensile Strength, Ultimate	440 MPa
Tensile Strength, Yield	370 MPa
Elongation at Break (In 50 mm)	15.00%
Reduction of Area	40.00%
Modulus of Elasticity (Typical for steel)	205 GPa
Bulk Modulus (Typical for steel)	140 GPa
Poisson's Ratio (Typical For Steel)	0.29
Machinability (Based on AISI 1212 steel. as 100% machinability)	70%
Shear Modulus (Typical for steel)	80.0 GPa

Aluminum 7xxx Properties

The Aluminium-7xxx is very strong among all aluminium alloys. It is well known for its high strength, which makes it is very useful in aerospace, aviation, marine and transportation applications. The Trade names of 7xxx are Zicral, Ergal, and Fortal Constructal. Some of the 7xxx series alloys sold under brand names, such as Alumec 79, Alumec 89, Contal, Certal, Alumould, and Hokotol [44].

Table 2: Mechanical Properties of Aluminum-7xxx

Properties	Metric
Tensile strength	260 MPa
Yield strength	95 MPa
Shear strength	150 MPa
Fatigue strength	160 MPa
Elastic modulus	70-80 GPa
Impact strength	04 (J)
Poisson's ratio	0.33
Elongation at break	17%
Hardness	120

Parameters Selected

Parameters considered to conduct the experiments by Friction Stir Welding with different preheating conditions to join aluminium 7xxx with Mild-Steel for constant thickness up-to 04 mm were carried out. Preheating of base materials is done along with (just before) Friction Stir Welding for following combinations. An L9 Orthogonal Array (3^3) was selected for current research work to optimize the process parameters of Preheated Friction Stir Welding of Mild-Steel and Aluminium 7075. This array requires nine trial runs and has three columns.

Table 3 Process Parameters for Preheated Friction Stir Welding

Level	Tool Travel Speed (mm/min)	Tool Rotational Speed (rpm)	Preheating Temperature (°C)
Range	16 - 40	750 – 200	75 - 200
Level 1	16	1000	100
Level 2	20	1400	150
Level 3	25	2000	200

WELDING PROCESS

All welds were made on a moderated milling machine with a suitable FSW tool and joints were butt welded for selected parameters for 9-Sets of experiments and post weld joints were subjected to NDT testing, then mechanical and microstructural examinations to examine the joint properties.

RESULTS AND DISCUSSIONS

The **Table 4** shows the Mechanical Test Results of ***'With Preheated Friction Stir Welded'*** joints, which were subjected to process optimization by **TAGUCHI'S** method to analyse best combination of parameters to get better joint strength.

Table 4: Tensile, Impact and Hardness Results of Preheated FSW Joints

Experiment number	Traverse Speed (mm/min)	Rotational Speed (rpm)	Preheating Temperature (°C)	Tensile Strength (MPa)	Impact Strength (J)	Hardness (HV) at Nugget Zone
1	16	1000	100	46.075	10.88	89.33
2	16	1400	150	130.36	15.33	230
3	16	2000	200	32.16	10.66	70.66
4	20	1000	150	45.396	10.83	100.66
5	20	1400	200	65.29	13.33	137.33
6	20	2000	100	100.24	15.16	215.66
7	25	1000	200	66.998	13.66	136.66
8	25	1400	100	51.701	12.50	180.33
9	25	2000	150	93.137	14.33	188.33

Tesile Strength

Figure 2 shows the effect of preheat temperature on the tensile strength of FSWed dissimilar materials. The maximum strength of joint fabricated at travel speed 16 mm/min, rotational speed 1400 rpm, and preheating temperature 150 º C. The results indicate that the tensile strength of Preheated-FSW welds is improved with increase in preheating temperature up to some optimum value.

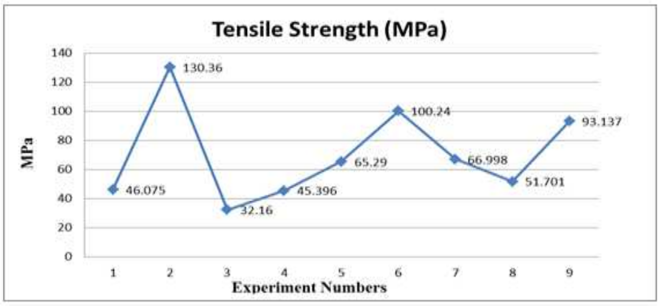

Figure 2: Tensile Strength of Joints Welded at Different Process Parameters

Figure 2 depicts the percentage of elongation for tensile test specimens. There is remarkable difference in percentage of elongation for friction stir welded with-preheated specimens for all the experiments. The experiment – 2 shows more percent of elongation compared to other experiments, due to better mixing of (Al and Fe) dissimilar materials.

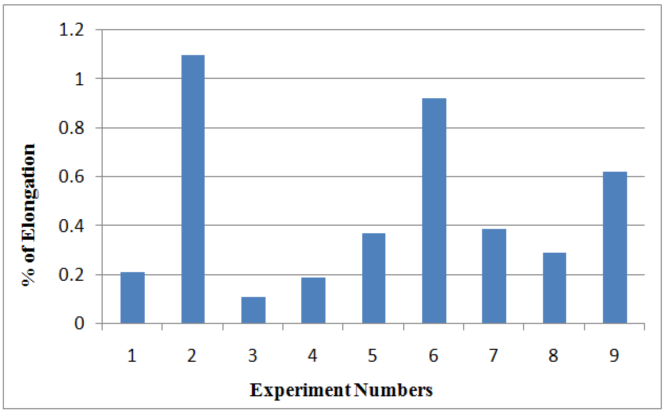

Figure 3: Comparisons between the Percentage of Elongation for Preheated FSW Joints

Toughness

From the experimental results it was observed that the impact strength is almost same for experiment number – 02 and 06, whereas lower impact strength is observed for lower rotational speed / lower preheating temperature and at higher rotational speed / higher preheating temperature. It is also observed that higher impact strength is achieved if rotational speed is greater than 1000 rpm.

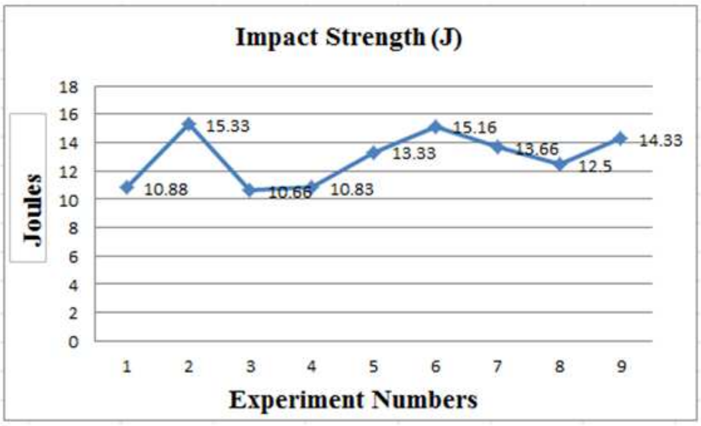

Figure 4: Impact Strength of Joints Welded at Different Process Parameters

Hardness Number

The microhardness profiles of all joints were measured at the center line of the cross section of the weld i.e., at stir zone (Nugget Zone). The average hardness value at the nugget zone of experiments 1 - 9 are 89.33, 230, 70.66, 100.66, 137.33, 215.66, 136.66, 180.33 and 188.33 HV respectively. From hardness diagram, it was revealed that the TMAZ - MILD-STEEL hardness value is considerably higher than HAZ - MILD-STEEL.

From the experimental results, it can be illustrated that higher hardness value was observed for traverse speed 16 mm/min, rotational speed 1400 RPM and preheating temperature 150ºC, whereas a lower hardness value was observed for 16 mm/min, rotational speed 2000 RPM and preheating temperature 200ºC.

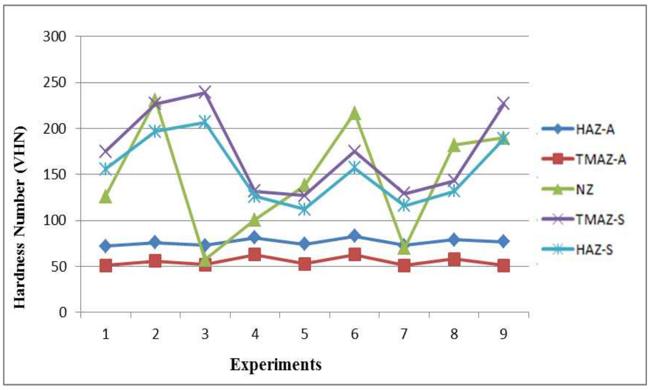

Figure 5: Hardness Number (VHN) at Various Zones

Micro Structural Calculations

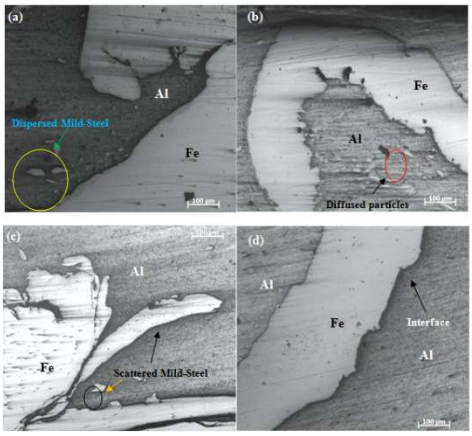

Figure 6: Microstructural Results of Experiment – 2

The **Figure 6** shows the microscopic characteristics of welded joint for experiment - 2. It was observed that few scattered Mild-Steel particle movement after straining, it may be due to preheating, frictional heat and forward movement of the tool. A small Mild-Steel particle was diffused nearby interface. The precipitated Fe-Al was fully diffused at nugget zone and also seen at the interface (i.e. good intermetallic bonding between atoms at interface).

CONCLUSIONS

The results related to mechanical and physical properties of preheated friction stir welding with different conditions were summarized as below:

- From the mechanical test results it is observed that, the joint strength of Preheated Friction Stir Welding is better than Without-Preheated Friction Stir Welding joints, this is mainly better mixing of both the material due to preheating the work-piece.
- The strength of joint increased by around 12% when joining was done With-Preheated Friction Stir Welding.
- The tool life was increased when joints were done with preheated FSW.
- Plunging was quite easy in preheated FSW as compared to without preheated FSW.
- Better (IMC) intermetallic composition in preheated FSW at weld zone as compared to without preheated FSW.

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